COMPARATIVE STUDIES OF THE *JOSHI-EFFECT* WITH A VACUO-JUNCTION AND DIODE DETECTION

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ABSTRACT. Production of the *Joshi-Effect*, an instantaneous and reversible photo-diminution Δi of the discharge current i is studied in chlorine excited by 2·6 kV at 50 cycles frequency. A vacuo-junction and double diode (the latter being coupled inductively and resistively with the L.T. of the ozoniser) served as detectors. As established by Joshi, Δi does not occur below the 'threshold potential' and that $\%\Delta i$ is maximum near it. Based on Joshi's result that Δi predominates in the high frequency part of i, an explanation is developed for Joshi's general finding that $\%\Delta i$ decreases by increasing the circuital resistance, on an analysis of the behaviour of the H.F., L.F. and supply frequency parts of i in terms of the corresponding damping and skin effects.

INTRODUCTION

The marked dependence, on the nature of the operative conditions and of the current detector employed, of the magnitude of the above phenomenon was emphasised by Joshi (1943, 1945a). Metal oxide and similar type rectifiers and subsequently low resistance Cambridge vacuo-junctions were used in these Laboratories during earlier work on this effect. Their use limited appreciably the range of the working conditions such as, for example, the magnitude of the applied potential (kV), etc. In the present work, the *Joshi-Effect* Δi was studied using a double diode as a current detector, which comparatively is less subject to the above limitations. This arrangement has revealed that the magnitude of this phenomenon can be as high as 81% current decrease with but ordinary light.

EXPERIMENTAL ARRANGEMENT

The general apparatus and the circuit used are shown in Fig. 1. Chlorine gas, purified carefully over liquid air, was contained in the annular space of a Siemens' type ozoniser at about 200 mm. pressure and excited at potentials varied in the range 2·6 kV (r.m.s.) at 50 cycles frequency. The discharge current i was measured (i) in dark and (ii) under irradiation from one 220 volt, 200 watt incandescent (glass) bulb by manipulation of the shutter shown in Fig. 1.

Three series of observations of i were made. In the first, the low tension electrode of the chlorine tube, L.T., was earthed directly through a vacuo-junction connected to a reflection galvanometer with an appropriate shunt. This part of the circuit is shown by α in Fig. 1.

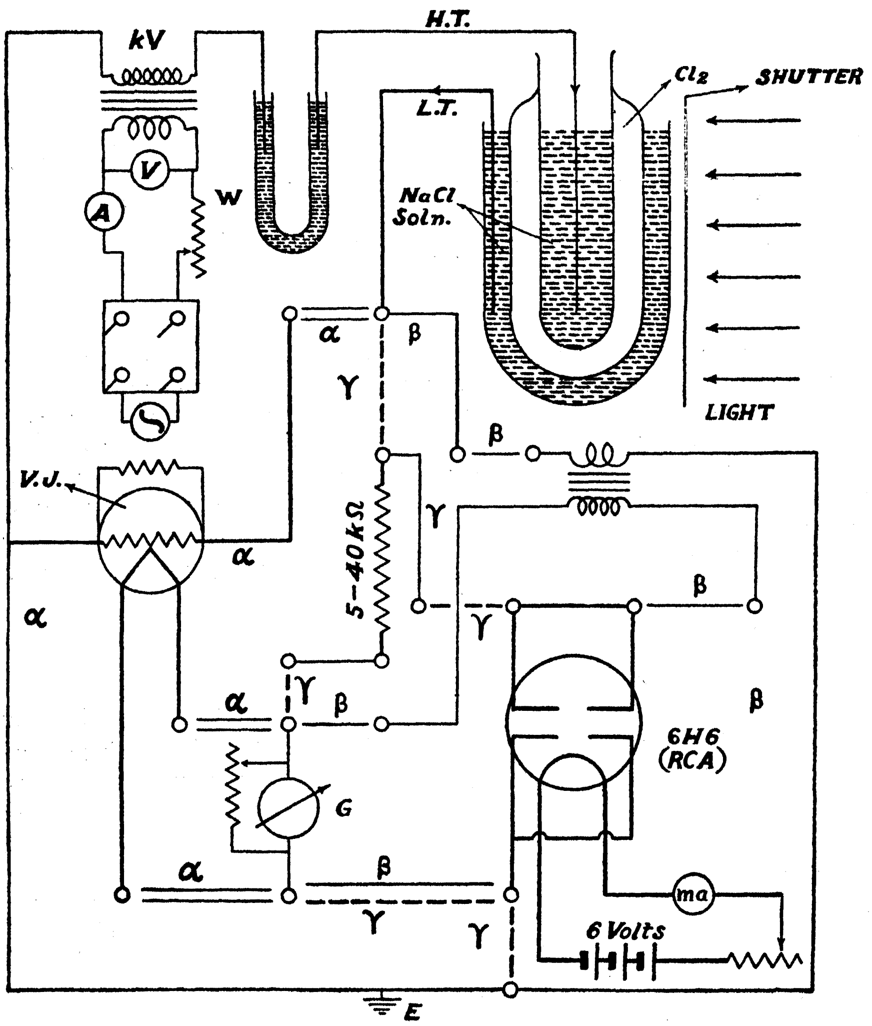

FIG. 1

Production of *Joshi-Effect* in chlorine

In the next series, a double diode, 6H6 (RCA), was used as a half-wave rectifier by short circuiting the two plates : the cathodes were heated indirectly with 270 mA. D.C. from a storage cell. The discharge current i was allowed to flow through the primary of a Bell type iron core, step up transformer (1 : 3) ; its secondaries were connected to the plates and the cathodes through the galvanometer as shown by β in Fig. 1. Finally in γ in Fig. 1, the input to the diode was tapped from a non-inductive and practically non-capacitative Dubilier resistance R, varied in the range 5-40 kΩ.

Fig. 2 shows the characteristic current potential curves observed in dark and in light using a vacuo-junction, in the range 2-6 kV applied to the ozoniser. In experiments to which Figs. 3 and 4 refer the vacuo-junction was substituted by a double diode, coupled inductively and resistively with L.T. respectively. From these curves the net *Joshi-Effect* Δi, using a given detector, can be obtained at a given kV ; the relative *Joshi-Effect* $\%\Delta i$ is $\Delta i \times 100/i_{dark}$.

DISCUSSION

During these observations the fundamental importance of the ' Threshold-potential ' V_m (Joshi, 1929, 1945b), for reactions under electrical discharge in general and the *Joshi-Effect* in particular, were noticed (Joshi, 1945b, 1944). Below V_m, which depends upon a number of operative conditions such as temperature, gas pressure and especially frequency, the *Joshi-Effect* is not noticed. It is interesting to observe that the curves in Figs. 2, 3 and 4 show that despite the widely divergent modes of i measurement, V_m for the above chlorine tube was about 2.4 kV. The maximum $\%\Delta i$ indicated by the vacuo-junction was about 64 at 2.93 kV ; and that with the diode fed inductively, from the L.T. circuit of the excited ozoniser, was about 81 at 2.67 kV near V_m (Joshi, 1945c). It is also seen that an increase of kV increases i and also Δi, the corresponding $\%\Delta i$, however, decreases (Joshi, 1943). In agreement with previous results (Joshi, 1945c), it is found that $\%\Delta i$ is reduced greatly in the resistive coupling of the detector diode. At $R = 5{,}000$ ohms, the maximum $\%\Delta i$ is only about 10, the operative conditions being the same as those with the other detectors. Furthermore, as compared with results with inductive coupling, this maximum $\%\Delta i$ occurs fairly above V_m. Results at greater R than the above value showed large i (input being larger) but a reduced Δi and $\%\Delta i$. It is significant that this influence of R in suppressing Δi and $\%\Delta i$ was markedly uniform under all conditions of excitation employed in this work.

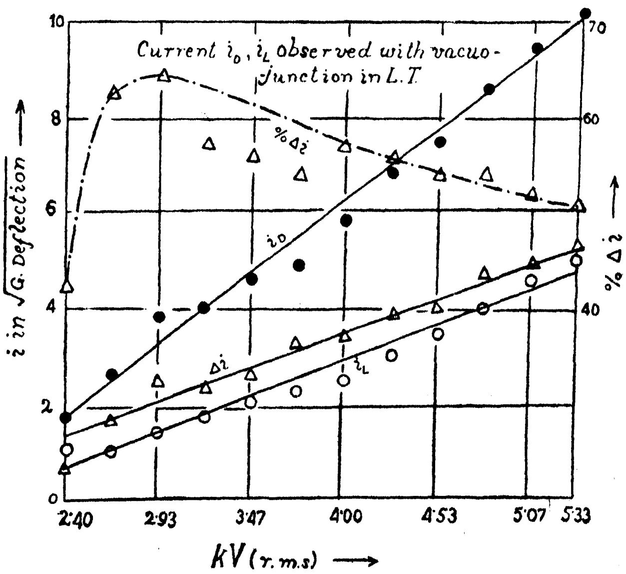

FIG. 2
Joshi-Effect with vacuo-junction detection

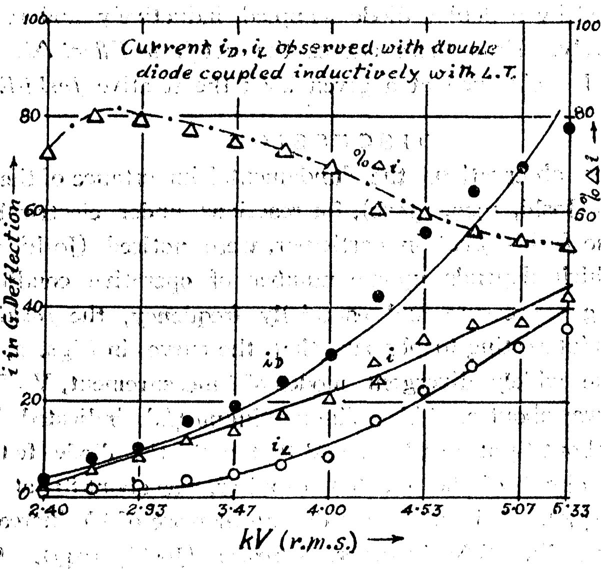

FIG. 3

Joshi-Effect with diode detection

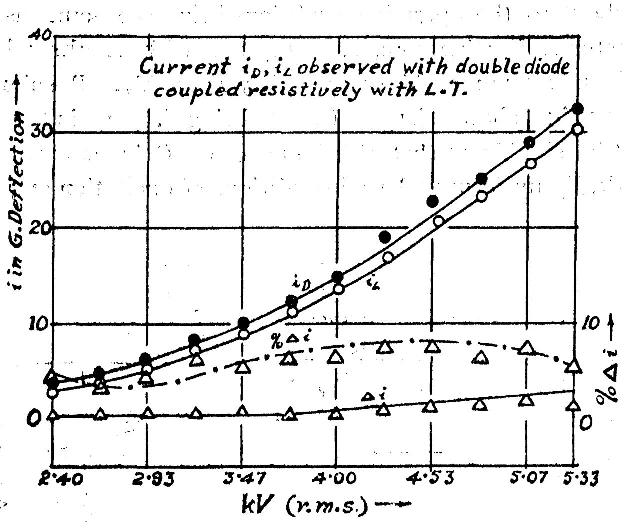

FIG. 4

Joshi-Effect with diode detection

From Figs. 2, 3 and 4, it is seen that the values for $\%\Delta i$ differ markedly with the mode of the current measurement employed. An explanation of this apparent variability is now suggested. From the oscillographic studies of the ozoniser, discharges under conditions appropriate to the production of large Δi (Joshi 1945a, 1945b, 1943), has established that (*a*) the discharge current i contains high frequency i_{HF}, low frequency i_{LF}, and the supply frequency component i_s and that i_{HF} represents the chief seat of this phenomenon Δi;

(*b*) the damping constants $R/2L$ of an oscillatory circuit consisting of R, the inductance L and the capacity C ; (*c*) the ' skin-effect.' From (*a*)

$$i_{dark} = i_{HF} + i_{LF} + i_{R} \quad \ldots \quad (1)$$

These quantities are added vectorially.

In order to realise the significance of (*b*), the state of an oscillatory circuit in which C stands for a compound (gas-solid) dielectric, should be taken into account. In a *forced* oscillatory discharge, the current flowing through the circuit is given by

$$I = I_0' \sin(\omega' t + \phi') + I_0 \epsilon^{-R/2L} \sin(\omega t - \phi) \quad \ldots \quad (2)$$

The symbols have their familiar significance. From (2) it may be deduced that the initial wave-form of the current would result from the superposition of an undamped wave of frequency f' and a damped one of frequency f. The former persists while the latter is damped at a rate that depends upon $R/2L$; finally I becomes equal to $I_0' \sin(\omega' t + \phi')$. It should be emphasised that equation (2) has been derived by considering the dielectric C to be in an unionised state. The *Joshi-Effect* is, however, observed only when the gas is ionised under the discharge. Besides, therefore, the two components in equation (2), an ionisation current consisting also of i_{HF} and i_{LF} is present. This non-sinusoidol ionisation current i_e (Joshi, 1945a, 1945b, 1943) may be expressed to a sufficient approximation by

$$i_e = \epsilon^{-R/2L} \{I_{m1}, \sin(\omega t + \theta_1,) + I_{m2} \sin(2\omega t + \theta_2) + I_{m3} \sin(3\omega t + \theta_3) + \ldots\} \ldots \quad (3)$$

where I_m represents maximum value of the current.

The ' skin-effect ' arises from the uneven radial distribution of current in a conductor ; the effective resistance R of a straight circular wire is given by

$$R' = R\sqrt{\pi^2 f \mu a^2 / \rho} \quad \ldots \quad (4)$$

where R is the D.C. resistance and the other symbols have their usual significance.

It is easily shown that in the inductive coupling $\%\Delta i$ would be largest due to the low (ohmic) resistance in the oscillatory circuit. On the other hand, with a resistive coupling and also in the vacuo-junction detection an appreciable resistance is introduced. This last increases the ' damping constant ' and also the ' skin-effect ' ; as a consequence a reduction of the HF oscillations occurs prior to irradiation, and therefore, in the corresponding $\%\Delta i$, as is actually observed. A like reduction in $\%\Delta i$ is not appreciable in a thermal device like a vacuo-junction, since the corresponding loss by resistive damping of i_{HF} is represented by conversion into heat. It is to be anticipated, therefore, that $\%\Delta i$ would decrease as R is increased. This is in agreement with the results. These considerations also account for the decrease in $\%\Delta i$ with increase in the exciting potential, since it has been found experimentally that as kV increases i_{LF} preponderates.

ACKNOWLEDGMENT

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REFERENCES

1 Joshi, 1929, *Trans. Faraday Soc.*, **25**, 120.
2 ,, 1943, Presi. Address, Chem. Sec., Indian Sci. Cong.
3 ,, 1943, *B. H. U. Journ.*, **8**, 99.
4 ,, 1944, *Curr. Sci.*, **13**, 253.
5 ,, 1945a, *Curr. Sci*, **14**, 67.
6 ,, 1945b, *Nature*, **154**, 147.
7 ,, 1945c, *Proc. Ind. Acad. Sci*, **22**, 4.